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CRLA/OIT Solar Photovoltaic Power Trailer Project Proposal

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Abstract:

Advancements in solar photovoltaic (PV) electricity generation have proven this type of renewable energy generation to be a viable, affordable, and proficient form of power when given adequate space and peak solar exposure. The ability now exists to provide sufficient power to remote locations through a low maintenance, pollutant-free, and endless source energy. Crater Lake National Park in Central Oregon provides an ideal testing ground for a solar PV system due to the remote location of the park and the high annual summer sun exposure that Klamath County, Oregon is known for. The distinctive conditions that exist at Crater Lake National Park require ingenuity within a unique design parameter. The historic nature and design of the buildings at Crater Lake prohibit stationary, structure-mounted PV system options. The high elevations and massive annual snowfall drastically increase maintenance requirements and the possibility of environmental damage to PV systems. The question arose of how to provide sufficient power to a primary structure at Crater Lake National Park with minimal maintenance, maximum system longevity, and maximum versatility. The decision was made to design and build a versatile and powerful solar PV power system on a 20 foot trailer that would offset approximately half of the annual power consumption of the Science & Learning Center (SLC) building at Crater Lake National Park. The trailer will be designed for safe travel, easy deployment, variable array angle, and the option of either grid-tie or remote operation. Results of implementation will demonstrate that the trailer power production is sufficient to supply half of the annual energy use of the SLC. The trailer will also provide added versatility in the form of remote power availability in emergency and maintenance situations. The solar trailer also presents options for multiple-use functionality in terms of education, public relations, and additional energy offsetting at the Oregon Institute of Technology in Klamath Falls, OR.

Introduction:

The net solar power input to the earth is more than 10,000 times humanity's current use of fossil and nuclear fuels (Boyle, 2004). All of the power that was necessary to produce the environment of pure, awe-inspiring beauty that is Crater Lake and the National Park surrounding it was provided by the sun. Why can't the sun be used to help power some of the facilities that provide park services that help keep Crater Lake pristine? Humans have been using the sun as a source of passive power for thousands of years to grow crops, warm houses, and cook and dry foods. It wasn't until fairly recently that technology has advanced to a point where humans can harness the sun's energy for direct power use in the form of electricity. Efficiencies in solar photovoltaic (PV) panels are still some distance from reaching the ninetieth and hundredth percentiles but they are improving at a steady rate. Crater Lake National Park would benefit financially, environmentally, and aesthetically through the incorporation of photovoltaic technology into their operational buildings during the regular visitor season. One of the issues with using solar power to offset energy use of any of the primary buildings at Crater Lake is that the buildings are beautiful, giant stone and wood structures that are protected by federal mandate from modern additions that will compromise the historic look and integrity of the buildings. Because of this federal mandate, photovoltaic panels cannot be mounted directly onto a building. Another issue is the immense snowpack which can be damaging to any equipment left exposed to the elements during the winter season. The decision was made to look at alternative and unconventional means of implementing solar photovoltaic power production into the challenging circumstances and environmental conditions of Crater Lake National Park. Could approximately half of the power usage at the Science & Learning Center in Crater Lake National Park be offset by a trailer-mounted portable solar photovoltaic array system?

The solar trailer will be designed to offset approximately half of the 7 kW of electricity that the Science & Learning center (SLC) uses throughout the year. The average energy use of the Science& Learning Center building was calculated by comparing several fiscal years of energy use records and estimating a current and projected average power use. Since power use varies from year to year depending on the employees assigned to the SLC and the projects that are being worked on, an approximation of average power use was established based on a multi-year average. There is a limited amount of space available for the solar trailer next to the SLC building so there is a size limitation for the trailer. In order to fully offset the SLC building it would have been necessary to have a 40 foot trailer and roughly 30 photovoltaic panels. This would have been both cost-prohibitive and too large in size for the scope of this project. The trailer will be designed for optimum mobility as well as multi-functionality. Given all environmental factors and equipment specifications in a controlled setting, the trailer will offset approximately 3000W to 3500W (W = watt) of power for the SLC. Unpredictability of environmental conditions, variance of equipment performance, and spatial restrictions could prove to be the largest variables for hypothesis error and will be evaluated at the end of the 2011 summer season.

Background:

There are several historical and current considerations that justify the need for the PV system and lead to a specific solar trailer design for Crater Lake National Park. Relevant solar photovoltaic technology; the location of the solar trailer project and government incentives that support the project; available solar photovoltaic technologies; special considerations and needs for implementation of the solar trailer in the unique environment of Crater Lake National Park; and examples of similar projects. Finally there are resource sharing considerations, and educational and public interest opportunities.

Solar Photovoltaic Systems and Available Technology

The photovoltaic effect was first accredited to a French physicist named Edmond Bacquerel in 1839 (Boyle, 2004) and later developed in theory and explanation by Albert Einstein, winning him the Nobel Prize in physics in 1921 (U.S. Army, 2000). The concept of the photovoltaic effect can be described as the process wherein the radiant energy of the sun is converted directly to electricity. The actual process is fairly complex and involves advanced chemistry, quantum physics, and electron transfer. The primary premise is that when photons from sunlight strike a specific material surface, electrons are freed within the material creating an electrical current. Most photovoltaic cells are made of silicon semi-conductor material that has been embedded or "doped" with impurities and special additives to aid in conductivity. Although the photovoltaic effect was first discovered in 1839, the first PV cell was not developed until 1954. In 1958 the first PV cells were being used to provide power for US spacecraft and satellites. Some of these original PV systems are still in use in space today (Thomas, Post, & Vanarsdall, 2004). Solar PV technology received a giant boost in production and use during the energy crisis of the 1970's. Shortages in gas and oil supplies spurred public and governmental support for alternative energy options, but the boost was short-lived. Support for PV technology advancement greatly reduced as the crisis ended and oil and gas prices fell to affordable rates. Solar PV technology advancement, production, and use took another significant leap forward in the 1990's and have been growing steadily since. In fact, according to a Department of Energy (DOE) program, the average cost of production of PV cells decreased by approximately 60% and the US production capacity increased sixteen fold between 1992 and 2002 (Surek, n.d.). This type of PV use and growth is not limited to the United States alone. Many European countries are leading the technology race in development and implementation of solar photovoltaics. Worldwide PV cell and module production has increased from 33.6 MW (MW = megawatt) in 1988 to 560.3 MW in 2002 with an increase from 390.5 MW to 560.3 MW in 2001-2002 alone (Surek, n.d.).

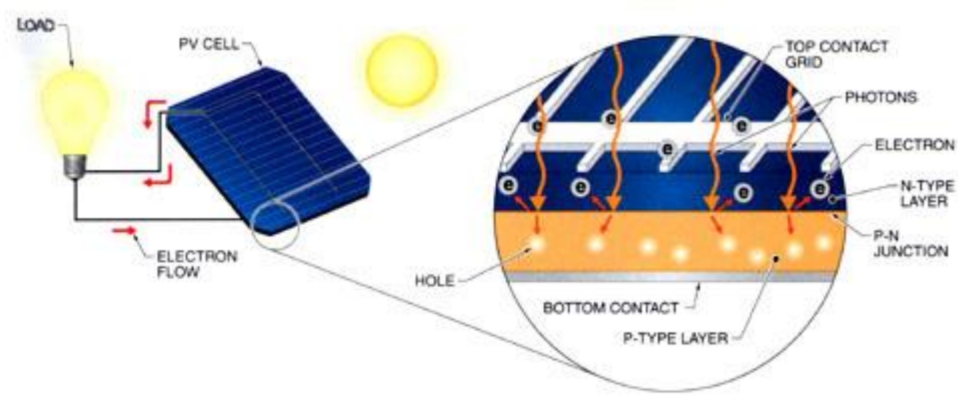

Figure 1: The Photovoltaic Effect is the driving mechanism in power production for the proposed Crater Lake National Park photovoltaic power trailer (Precision Power, Inc., 2010).

<u>Science & Learning Center, the National Park Service, and Federal Government Energy Initiatives</u>

Crater Lake is located in Central Oregon; it is isolated within Crater Lake National Park which is an amazing assortment of dense timber land, creeks, trails, and cliffs. The park receives an average of 533 inches of snowpack each year equaling approximately 44 feet (National Park Service [NPS], 2010). The primary operating season for the park is June through October. The rest of the year travel, recreation, and visitation is greatly limited due to snowpack. The park receives significant sun exposure during the primary operating months and solar power is used for specific purposes elsewhere in the park. Solar power systems can be found in campgrounds, at the north entrance fee station, and down in the caldera. These systems provide power for restroom facilities and operational needs like motors, computers, and radios in places such as the Wizard Island boathouse.

The Science & Learning Center building is the primary test site for the PV trailer project and is located at the north end of the park headquarters complex (see Figures 2 and 3). The SLC building is a cooperative research and education center and is an ideal testing point for the solar trailer project. The building has a large, open stretch of field to the east entirely exposed to the sun and an electricity grid power hub is located approximately 100 meters from the building.

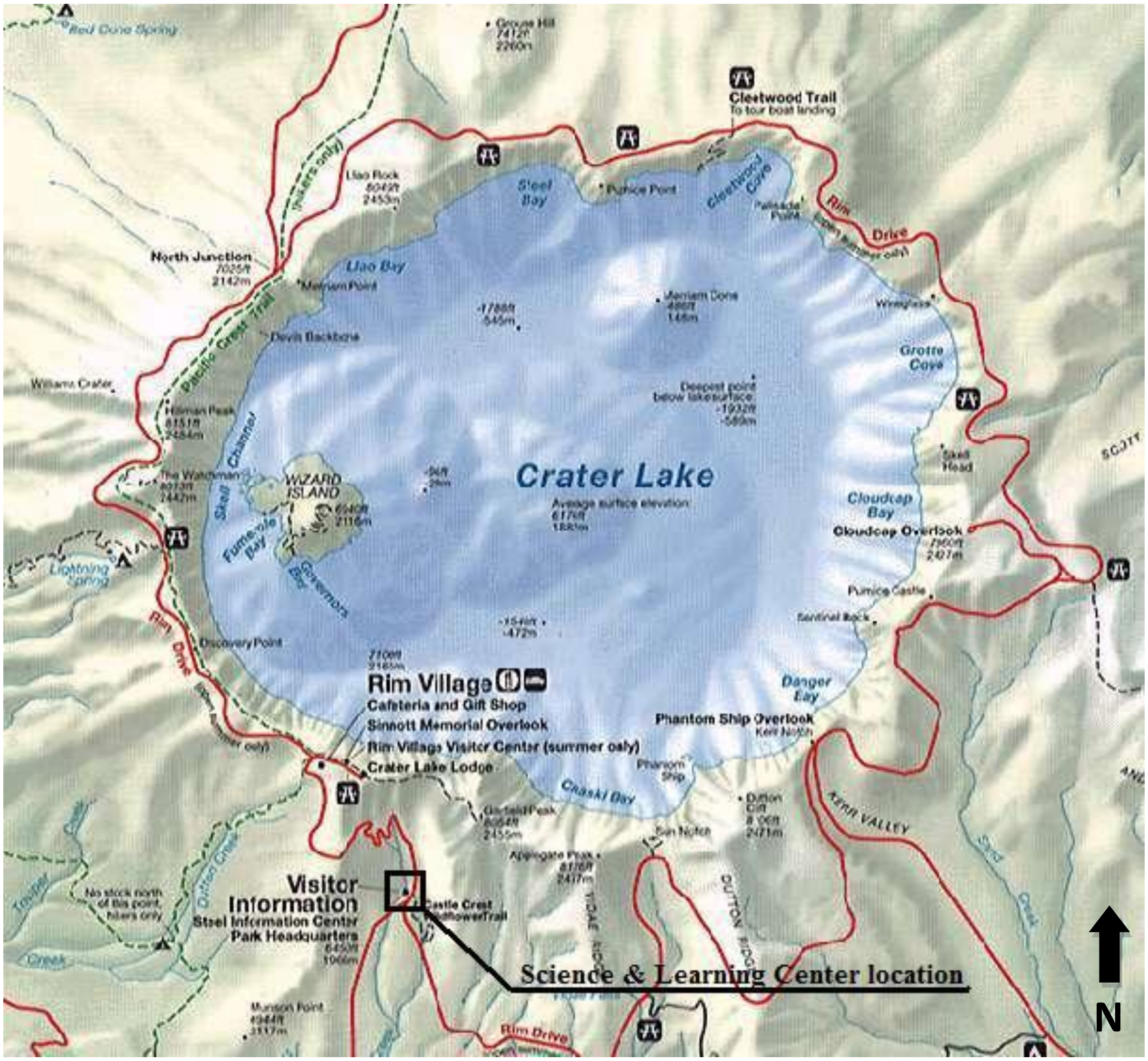

Figure 2: Photovoltaic trailer proposed project site at the Science & Learning Center, Crater Lake National Park (NPS, 2010).

Figure 3: Crater Lake National Park headquarters and Science & Learning Center building location, site of the photovoltaic trailer project (Google Earth, 2011).

The National Park Service regularly evaluates and budgets for clean energy technology additions and upgrades. The park currently uses photovoltaic technology for power at remote locations such as the north entrance fee station, the bathrooms and water pump at the Cleetwood boat launch, and the boathouse station on Wizard Island. These systems are significantly smaller in size than the trailer system. They are also lower wattage, pole or building-mounted stationary systems with no mobility or array adjustment capabilities. Numerous other parks throughout the National Park Service system have incorporated or are planning to utilize photovoltaic systems to offset or partially offset business, visitor, and residential power use within the parks. These efforts are in correlation with the Federal Government's mandates and goals on energy reform and pollution production mandated in legislations such as the National Energy Conservation Policy Act, Energy Independence and Security Act, Executive Orders (EO) 13514, 13423, 13221, the Energy Policy Act of 2005, and the NPS Climate Friendly Parks Initiative. As an example, E.O. 13423 requires that Federal agencies must ensure that at least half of all renewable energy required under Energy Policy Act (EPAct) of 2005 comes from new renewable sources and to the maximum extent possible, renewable energy generation projects should be implemented on agency property for agency use (Executive Order #13423, 2007). The Federal Government is actively promoting advancement and implementation of numerous renewable energy technologies including photovoltaic systems. The chart below shows U.S. funding of alternative power technologies in the fiscal year of 2001. Photovoltaic power was the highest funded alternative energy technology in the U.S. in 2001.

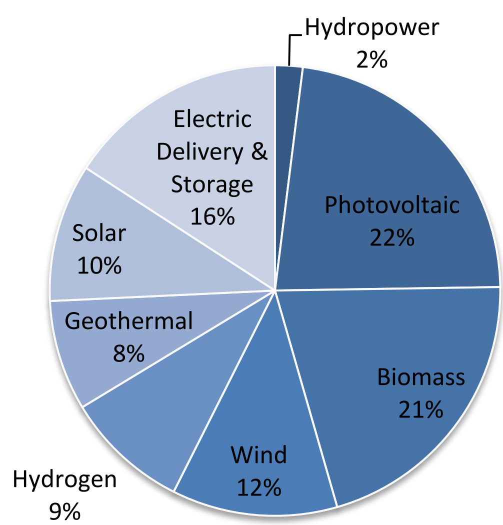

Figure 4: Fiscal year 2001 U.S. alternative power technologies funding showing the largest focus on solar photovoltaic energy (Herrick, 2003, p.89).

According to one report, “The federal government is the single largest energy consumer in the nation… In Fiscal Year 2000, the federal government spent $4 billion on energy for its buildings … This creates an environment ripe for the implementation of energy efficiency mechanisms… executive orders set out goals for the federal Executive Branch to reduce greenhouse gas emissions and to promote renewable energy use… the orders require, in effect, an internal federal renewable portfolio standard of installing 20,000 solar energy systems at federal sites by 2010” (Herrick, 2003, p. 107-108).

Available Solar PV Technology Options

There are various types of materials and chemicals used for PV panels ranging in efficiencies, longevity, and expense. Some material types contain small amounts of toxic substances such as cadmium telluride and copper indium gallium selenide that could possibly pose a risk if a fire in the array were to occur, but the chances of such an event are extremely low. Photovoltaic systems generate no noise, no gaseous or liquid chemical pollutants, and no radioactive substances during use and the environmental impact of PV technology is generally seen as benign (Tsoutsos, Frantzeskaki, & Gekas, 2005). Table 1 shows a comparison of popular PV material technology efficiencies.

Table 1: Efficiency of solar PV technologies as of September 2009 (The Green Investor, 2011).

Technology	Efficiency
Crystalline silicon	
Monocrystalline	19% (cell) 25% (cell lab record) 17% (module)
Multicrystalline	17% (cell)
Thin film	
Cadmium telluride (CdTe)	11% (module)
Copper indium gallium selenide (CIGS)	8-10% (module) 20% (cell lab record)
Amorphous silicon	6% (module)

When evaluating longevity of the system, toxicity of the material, energy efficiency, and cost, it was determined early on that the solar trailer should incorporate either monocrystalline or polycrystalline silicon PV cells. These cells are affordable with no toxicity levels, 30-year average lifetime ratings, high durability, and sufficient output ratings. They are also the most established and well-documented of the PV technologies available. The unique environmental conditions of Crater Lake National Park coupled with the versatility and mobility of the power unit specific to the trailer design later led to the decision to use monocrystalline silicon PV modules on the prototype solar trailer unit.

Special Considerations, Needs and Examples for Implementation of the Solar Trailer into CRLA

Peak solar exposure must be calculated in order to properly size a photovoltaic system and to analyze the potential effectiveness of the system. The location that is being used to calculate peak solar exposure for the PV system on the trailer is Klamath Falls, Oregon. Peak solar exposure has been calculated for areas all across the country in a national database. This database includes Klamath Falls but does not list specifically for the SLC location at Crater Lake National Park. The SLC location is similar enough in average sun exposure that the peak solar exposure rating for Klamath Falls can be used for PV array sizing and efficiency calculations. Air temperature is several degrees cooler on average at Crater Lake as compared to Klamath Falls but air temperature is a negligible factor in sizing of the array system between the two locations. Larger concerns are the ridges and mountain ranges surrounding the SLC building. Initial calculations show that although there is a minor difference in sunrise and sunset exposure times, it will not be significant enough to affect peak solar exposure and array efficiency. Tree shading is a concern but initial visual research over the period of June, 2010 to September, 2010 shows that no tree shading reaches the primary designated location for the solar trailer. Factors to consider for design and implementation include elevation and inclement weather. Temperatures can shift from the mid-80 degree range to below freezing in a 24 hour period. Electronic components and battery compartments will be covered and sealed to prevent condensation and rain/snow exposure that would permit repeated freezing and thawing and potentially damage components. The trailer has been designed to allow the arrays to be folded down and secured against the sides of the trailer for both transportation and severe weather events. PV panels and systems are largely considered low maintenance, but natural elements such as pollen, dirt, dust, leaves, pine needles, and other debris can accumulate on the panel surface reducing efficiency of the system (U.S. Forest Service, n.d.). Regular maintenance in the form of checking and cleaning the panel surfaces will be necessary, but will be minimal in nature due to ease of access to the system and availability of cleaning tools such as dusters, brushes, and squeegees on extendable handles.

Permitting and regulations for use of the trailer are minimal due to the portable nature of the PV system. Environmental impact concerns have received initial evaluations from Crater Lake National Park and approval of the project implementation has been given. The installation of the PV system (see Figure 5) and integration into the Science & Learning Center structure is being performed by a certified photovoltaic solar installer, Ecosolar, Inc., a local company based in Klamath Falls. A representative of the power company will be required to install a net metering bidirectional meter system on the power hub at the trailer site. By incorporating a net metering system, exported power from the solar trailer makes the electric meter run backward, crediting the PV system owner for power supplied to the utility grid at the retail rate. It is necessary to obtain an interconnection agreement and a net metering agreement from the power provider as well. The interconnection agreement specifies the terms and conditions under which the system will be connected to the utility grid and the net metering agreement specifies the details of the excess power buyback when the PV system produces more electricity than the building is using (U.S. Department of Energy, 2003).

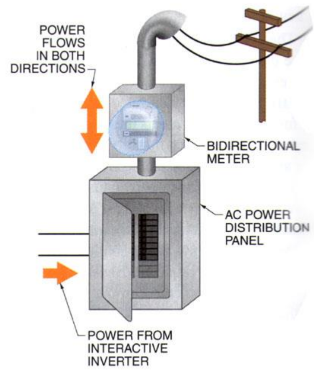

Figure 5: Basic diagram of a net metering system that will resemble the one used with the proposed Crater Lake National Park photovoltaic power trailer (Precision Power, Inc., 2010).

Ecosolar, Inc. recently designed and built a 2.46 kW solar PV trailer for the Oregon Department of Forestry (ODF) in 2009 (see Figure 6). The solar trailer provides the ODF Camp 6 guard station with power during the summer months and offsets power use in the buildings at the ODF Lakeview unit during the winter. Camp 6 is an isolated location and would have required approximately $175,000 to connect to grid power. The solar trailer and one year maintenance and operation cost approximately $44,000, estimated at paying for itself in 10 years. The system also took the place of an over-sized and aging gasoline generator that was becoming very expensive to maintain, inconvenient to operate, and highly unreliable (Gustaveson, 2011). This solar trailer is the primary example used in the design and adaptation of the CRLA solar trailer project.

Figure 6: Oregon Department of Forestry 2.46 kW solar trailer that was the template for the design of the proposed Crater Lake National Park photovoltaic power trailer (EcoSolar, Inc., 2011).

There are several examples of stationary photovoltaics implementation and even a few examples of mobile photovoltaics implementation in government facilities and operations. These PV systems are supplying soldiers in the Middle East with electricity, allowing satellites in orbit to move and operate by the power of the sun alone, powering remote weather and monitoring stations, pumps and recreational facilities in secluded areas of national monuments, parks, and forests, and offsetting power consumption of numerous federal buildings. This CRLA/OIT solar power trailer is the first of its kind in design, size, and function by being a cooperative, resource-sharing effort between Crater Lake National Park and the Oregon Institute of Technology.

<u>Resource Sharing Considerations, Educational and Public Interest Opportunities</u>

The PV power trailer was designed so that the PV arrays collapse and store easily along the side of the frame for stable and safe transportation and storage. The idea behind the design was to combine simplicity with versatility. The trailer will travel to different locations throughout the year and could be utilized in different settings. The design allows for either side of the trailer to face towards the light source and array angle adjustments for variations in locations, sun exposure, and time of year. One of the primary reasons for designing a trailer with this kind of flexibility is the ability to utilize the trailer in educational, public relations, and demonstration purposes for OIT's Oregon Renewable Energy Center (OREC) while not in use at the SLC in Crater Lake National Park. The trailer will also have the capability to be utilized when needed in emergency situations such as wilderness search and rescue, fires, flooding, and other natural disaster or incident staging areas where power is unavailable from traditional sources.

The Crater Lake National Park/Oregon Institute of Technology solar PV trailer will be a combined effort in innovation and renewable energy technology aimed at energy efficiency and versatility. The growing support and implementation of renewable energy and specifically solar photovoltaic power within the United States and the recent mandates within the federal government lead to a setting of perfect timing and motivation for a project like the CRLA/OIT solar power trailer. Technological advancements in PV cell development have provided an opportunity to supply the Science & Learning Center building with solar-generated renewable energy. New PV modules are more efficient than ever, allowing increased power production in a smaller area. The advanced technology available for the CRLA/OIT power trailer will be a key component in the design process. Fully integrated single-unit power systems, advanced monitoring systems, and powerful yet lightweight array panels provide an opportunity to create approximately 3000W of clean energy from a portable, 20-foot trailer photovoltaic system.

Methods & Materials:

Methods for research collection will primarily be internet resources of solar projects that are as similar to the project size and location details as possible, and direct contact with Ecosolar Inc. for calculating specific equipment size, style, and capability of the solar power trailer. Additional research collection will be obtained through contact with Crater Lake National Park for site-specific implementation guidelines, the local power company for necessary planning and procedure for net monitoring implementation, and the county code enforcement and permitting office to insure legality and compliance of the project in terms of electrical code and metering configuration. Some hands-on research will take place in the form of observation of existing local solar photovoltaic (PV) projects and an example solar power trailer that Ecosolar Inc. built for Oregon Department of Forestry a few years ago. The ODF solar power trailer is similar to, but not powerful or versatile enough for, the power needs of the CRLA Science & Learning Center. These research methods will support the hypothesis that a PV solar trailer can achieve the power output and consistency necessary to offset the electrical needs of the CRLA Science & Learning Center building.

The first step of the project is to analyze the annual power consumption of the Science & Learning Center (SLC) using previous fiscal year energy use reports for the SLC to determine the system size that will be needed. This can be used to calculate the power output rating needed for the system and the peak solar exposure rating for the area of Crater Lake National Park. Once these factors are combined to determine the size of the array and power system, a trailer design can be determined. The design must be specific to the parameters of the location for solar availability. Additional design criteria for the SLC project include maneuverability, versatility of use, and array angle adjustment capability.

The design of the solar trailer was completed in collaboration with Ecosolar, Inc. It was determined that a 20-foot trailer would be an ideal size for the project in order to produce significant power and maintain sufficient mobility in tight spaces. The trailer size limited the number of panels that could fit on the array. The array was designed into two separate sections; one section for each side of the trailer. A modified A-frame design was created to maximize trailer mobility, operational setup, and array angle adjustment.

Materials for the construction of the PV trailer include a 20-foot custom built flatbed trailer, a self-contained power conversion and supply system, a remote monitoring system, deep cycle batteries, wiring and connectors of varying wire gauges, a 12 to 16 solar panel PV array, equipment storage compartments, and the array angle adjustment mechanism. Necessary equipment for monitoring and maintenance include a computer with internet access, a 4 GB or larger storage flash drive, a digital camera for photo documentation, a digital multimeter for verifying voltage and current measurements, a meter for measuring solar exposure, and a laptop computer with Excel for tracking results.

These choices were made specifically to fit industry-standard testing and use parameters, standards for working with solar panels, and also for accuracy and confidence of tracking results. The solar exposure meter will allow for location-specific information about movement and location of the sun throughout the day and intensity of solar exposure in relation to time. Most other items are either necessary for collecting data or will be convenient in keeping organized and documenting process and progress.

Once the trailer is complete and other materials are obtained, the trailer will be taken to Crater Lake National Park and set up in the field next to the Science & Learning Center building. The trailer array will be connected to the electricity grid at the power meter near the top of the driveway. Once connected, the system will operate constantly during sunlight hours for approximately three months. System production data will either be streamed to a computer via the internet or collected at least every two weeks manually on a flash drive. Regular cleaning maintenance must be performed every two weeks at a minimum to ensure the array panels are clear of dirt, pollen, and debris to keep the panels operating at optimum performance. Regular visits to the system will be made throughout the summer of 2011. Data collected will be recorded on field report sheets (see Appendix 1).

The energy production data will be analyzed using Minitab statistical software. An ANOVA test will determine mean average power production and establish a comparison between theoretical equipment yield provided by the manufacturer established using PVUSA test conditions and actual equipment yield recorded during field testing. The actual average yield of the PV power trailer will then be compared with the average annual energy use by the SLC to demonstrate the hypothesis that the proposed PV solar trailer can offset approximately half of the annual energy consumption by the SLC building and its regular operations.

Field Safety:

The largest threat to field safety is the possibility of electric shock. The system will be capable of producing nearly 3,000W of power. It will contain many large batteries connected in series, and will be connected to the electricity grid which often supplies approximately 200 amps of power to most house-sized structures. As little as 0.03 to 0.07 amps is enough to impair a person's ability to breathe. Currents in the range of 0.1 to 0.2 can cause death by defibrillation or uncontrolled twitching of the heart, and any current much above 0.1 will usually bypass defibrillation and stop the heart completely (Michigan State University, 1992). The trailer system is contained and insulated making likelihood of shock very low. Nevertheless, there is a risk of injury, burns, organ and brain damage, and death that accompany working with any significant electrical loads. Wiring and electrical insulation should be checked regularly, unusual buzzing or humming noises should be investigated, and any erratic changes in power production or data results should be checked for shorts and disconnects in components. The solar PV power trailer, the array, the batteries, and the general equipment are very heavy and mobile. There will be large, moving components with pinch and crush points that need to be well marked and avoided.

Location:

The general application area for testing of the solar PV power trailer will be Crater Lake National Park. There are several areas in which the trailer could be utilized once completed and operational. These areas include the headquarters buildings which includes the SLC building, the visitors' center at the rim of the lake, the north and south entrance fee stations, and several visitor viewpoints around the lake rim drive. Figure 7 is a map of the general location of the PV trailer's primary application region and the project test site near Crater Lake. The second map (Figure 8) gives a layout of the park headquarters and location of the SLC building where the primary test site for the trailer is planned.

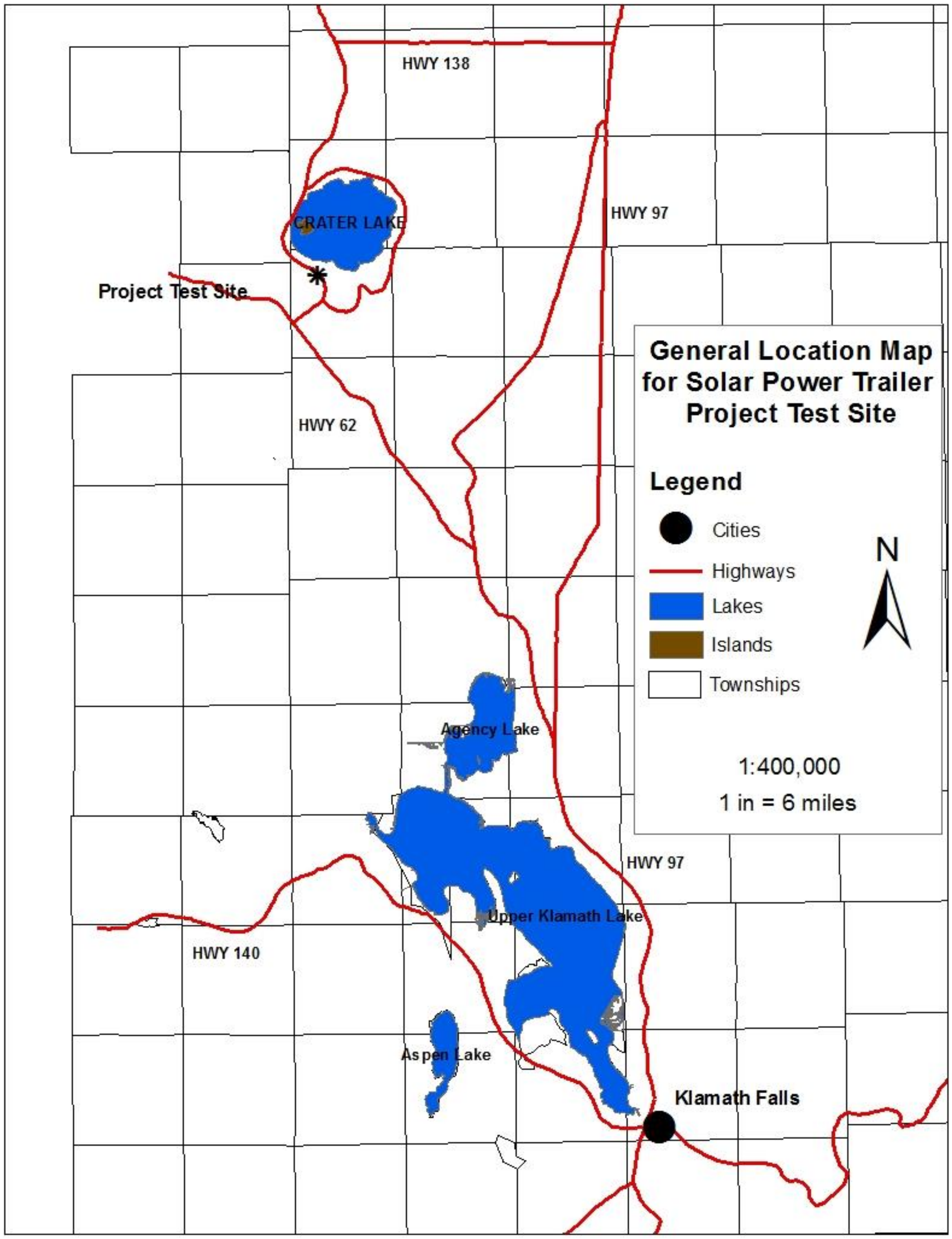

Figure 7: ArcGIS general location map of Crater Lake/Klamath Falls area. The solar trailer will be designed and built in Klamath Falls but will be used at the Crater Lake National Park Science & Learning Center.

Figure 8: Arial Satellite hybrid map of Crater Lake National Park headquarters, the Science & Learning Center building, and the project test site (Modified from NPS, 2011).

The Science & Learning Center building is a majestic, old stone and timber house at the top of a hill at the north end of the park headquarters complex. The SLC building used to be the old park superintendant's residence, but has since been remodeled and turned into a cooperative research and education center between the National Park Service (NPS), Southern Oregon University (SOU) in Ashland, Oregon, and Oregon Institute of Technology (OIT) in Klamath Falls, Oregon. The SLC is an ideal testing point for the solar trailer project. The building has a large, open stretch of field to the east entirely exposed to the sun. This open area covers approximately half an acre and receives adequate solar exposure throughout the day meaning that no tree or building shading will affect the solar array during the maximum solar exposure times of the day. The road to the SLC parallels the south edge of the field and an electricity grid power hub is located approximately 100 meters from the building on the edge of the road at the bottom of the open field. This is the site location for the solar trailer. This location will give the solar trailer ideal access to both the SLC building power meter and the main grid tie-in location.

Figure 9: The Science & Learning Center at Crater Lake National Park, site of solar trailer project data collection 2011.

The PV power trailer will be located several meters east of the Science & Learning Center Sign seen in Figure 9.

Quality Assurance, Quality Control (QAQC):

Problems that may be encountered during testing and data collection include software malfunctions or failure which would disrupt or stop data collection of power production over time. The unit will not be monitored constantly so if there is a software failure or malfunction, stalled data collection could span several days. The system is fairly maintenance free and should carry very little risk of hardware failure that would keep the arrays from creating power, but the potential for hardware failure still exists. The system is slated to have a remote monitoring unit of some type, which can recognize a system issue within a few hours of the event. Another major problem for data collection is the fact that this is an outdoor system that is highly dependent on solar exposure and weather. Weather can often be predicted in patterns or forecasts and conditions can be predicted relative to past years, but the weather over the course of a summer is unpredictable and may significantly fluctuate from the normal historic patterns. An intense rain and storm event during the summer season could create lower than expected power production from the solar PV unit. Severe weather events can also cause damage to the unit in the form of falling trees or branches. The unit will be located to avoid these circumstances and the arrays can be lowered to the frame during weather events. These precautionary measures should greatly reduce the likelihood of storm damage.

Instrument calibration will be minimal for the PV power trailer. Initial calibration of the power system and tracking software to specific settings will be the only calibration requirements for the project. The primary statistical analysis will be the average power production of the PV trailer and whether or not the system was able to offset approximately half of the SLC annual power use. This test will be performed using an ANOVA One-Way Layout test used for comparing simple relationship statistics between different means. Error will primarily be accounted for by relating outliers in the statistical set to possible environmental conditions such as excessive cloud cover or weather events by comparing the dates of the outliers with weather observations recorded by Crater Lake National Park and surrounding lookout towers.

Conclusion:

The portable solar PV power trailer project will be a mutually beneficial endeavor for Crater Lake National Park and Oregon Institute of Technology in both practical and educational realms. The multifaceted versatility of the PV power trailer will allow for self-contained, remote, renewable power production in a number of situations and settings. The trailer will be utilized to offset approximately half of the power needs of the Science & Learning Center during the peak summer months and spend the rest of the year at OIT or other NPS locations for offsetting power needs, educational purposes, and public relations events. The design, portability, and versatility of the trailer will help to promote incorporation of PV energy production in a variety of situations using unique and creative design concepts.

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Appendix 1

CRLA/OIT Solar PV Power Trailer Project	Scott McEnroe	Environmental Sciences Senior Project		
Data Collection Form	Date:	Time	Location	Elevation

Weather Observations:		Instantaneous PV Array Measurements from Power Monitor			
Clear Partly Cloudy Mostly Cloudy Overcast		Array voltage V_{DC} (V)		Grid voltage - V_{AC} (V)	
Precipitation: Yes No Notes:		Array current I_{DC} (A)		Grid (injected) current - I_{AC} (A)	
		Array power P_{DC} (W)		Grid (injected) power - P_{AC} (W)	
Wind Speed (v):		Module temp. T_{module} (°C)		Ambient temperature T_{amb} (°C)	
Wind Direction:		Solar radiation G (W/m^2)		Daily/monthly solar insolation - H (J/m^2)	

Environmentally-related notes or comments

Equipment Safety Check Performed	yes / no	Condition of Array Panels	clean / dirty	Any Damage to the Array	yes / no

Notes and comments on equipment, Harware, or Software:

Data Collection Range (days)	Data Size (MB)	Type of Data Device Used

Notes and Comments on Data and Data Collection Process: